Amer. Malac. Bull. **28**: 97-103 (2010)

Strategies for collecting land snails and their impact on conservation planning*

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Abstract: Land snail collecting methods are each designed with a particular purpose. This paper provides a brief overview of land snail collecting strategies, suggests the use of multiple methods and collection of ecological data to broaden the knowledge of land snail life habits and relationships with their environment, and indicates approaches that are most relevant to land snail conservation.

Key words: search methods, historical data, terrestrial snails, Pulmonata, Gastropoda

Land snails exhibit a wide range of habitat preferences, varying with species and region, but these generally reflect their main survival requirements: moisture, food, shelter, and a source of calcium for shell building and physiological processes (Burch and Pearce 1990). As a consequence, some of the greatest species abundance and richness occurs in moist, deciduous forest (Pearce and Örstan 2006). Nevertheless, snails have evolved to survive also in arid environments (Bequaert and Miller 1973). Fens, algific talus slopes, wetlands, and rock, particularly limestone bluffs are also habitat to various snail species (Nekola 1999). Most species require a humid environment and seek shelter in microhabitats such as under logs, rocks, leaf litter, in and around bryophytes, coarse woody debris, and moist vegetation. Other places that support snails include the interface regions of the forest floor, such as the crevices between a log and the ground litter and between exposed tree roots. It is often in these places that vegetation is found in a decomposing state, so these microhabitats are also important as areas for feeding because most land snails are generalist herbivores (Burch and Pearce 1990).

Many approaches for sampling terrestrial molluscs have been suggested in the literature. Most of these studies discuss methods in the context of a research project (Grime and Blythe 1969, Riggle 1976, Coney *et al.* 1982, Alvarez and Michael 1993, Emberton *et al.* 1996, Hawkins *et al.* 1998, Nekola 1999, Tattersfield *et al.* 2001, Hotopp 2002, Millar and Waite 2002), while others specifically address collection methods and comparisons between them (Bishop 1977, Boag 1982, Emberton *et al.* 1996, Cameron and Pokryzko 2005).

Historically speaking, most of the land snail collecting in North America has been qualitative, and many distributional records are simply the recorded presence of a species (Hubricht 1985). These records offer collectors useful baseline information on species, habitats, and ranges, and what habitats might still be best for populations of endangered species, where collection of live specimens is forbidden. Since the mid-20th century, collecting efforts in North America and elsewhere have turned more toward quantitative studies, often perceived as having greater scientific value. Such studies require that land snails are collected using some standard measurement, either by time, volume sampled (*e.g.*, of leaf litter, soil, etc.), or area, and often by some combination of these factors. Most often, snails collected in this type of study are also accompanied by habitat or microhabitat data, which is also measured in a quantifiable, repeatable way. When a collecting method is quantitative, the snail abundance and diversity counts can be legitimately compared, and more effectively used in statistical analyses. Many contemporary studies use quantitative methods of collection, from which population dynamics can be studied (Bishop 1977).

The choice of collecting method(s) is dependent upon (1) the extent and scope of the investigation, (2) the type(s) of terrain to be sampled, and (3) the intent of the investigation. Among the basic questions that require answers before making this choice are: Is the study exploratory in nature or does it have specific goals? Can the objectives be met with qualitative observations or does the study require quantitative data to answer specific questions? Does the investigation require (or would it benefit from) ecological and/or environmental data for comparison with species data? Regardless of the responses to these questions and the choices made, the most important consideration is that the methods are repeatable and that they have scientific rigor.

* From the "Leslie Hubricht Memorial Symposium on Terrestrial Gastropods" presented at the meeting of the American Malacological Society, held from 29 July to 3 August 2008 in Carbondale, Illinois.

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LAND SNAIL COLLECTING STRATEGIES

Qualitative visual searching

Qualitative observations are historically relevant, and in modern times often provide the first indication that a land snail survey is necessary, especially when unexpected species are casually encountered. Direct visual search is the simplest and least expensive method, but is of course restricted to species and specimens that are large enough to be seen in field situations. Qualitative data also have limited application in statistical analyses.

Even when quantitative methods are also used, supplemental qualitative searching can recover elusive or rare species not collected within the measured and/or timed searches. Most importantly, snails and slugs present on tree trunks and limbs or vertical rock ledges are usually not effectively sampled in quadrat samples. Hence, the inclusion of such qualitative collections, *i.e.*, collections made by direct visual searching, can maximize estimates of diversity.

Quantitative quadrats and transects

Many examples of quantitative sampling methods exist in the literature (Riggle 1976, Bishop 1977, Coney *et al.* 1982, Bengtsson *et al.* 1994, Emberton *et al.* 1996, Nekola 1999). For these types of surveys, it is most common to section an area into plots or linear transects, which usually comprise a gradient of the landscape. Quadrats, most often areas of one square meter or less, are demarcated on the ground using a frame (Bishop 1977, Emberton *et al.* 1996). Each transect, plot, or quadrat is visually searched for a predetermined length of time, *e.g.*, 30 minutes (Emberton *et al.* 1996). In areas of low-slope soft substratum, the entire contents of the quadrats (leaf litter, coarse woody debris, etc.) can be collected as a bulk sample and returned for sorting in the laboratory (Coney *et al.* 1982, Bengtsson *et al.* 1994). Replicate quadrats can be arranged along a linear transect (Alvarez and Michael 1993), randomly placed, or located using a stratified random sampling method (Bishop 1977, Emberton *et al.* 1996), in which replicate locations are randomly selected from areas most likely to include snails. The latter school of thought follows the understanding that snails tend to be patchy in distribution. Pearce and Örstan (2006) noted that they are most likely to be found under the bark of trees, near bases of rocks, under logs, and in other microhabitats that might be missed in a completely random selection of samples—but this approach has been criticized as biased preferential sampling (Cameron and Pokyryzko 2005).

The obvious major advantage of quantitative samples is that inter- and intra-site comparisons and statistical analyses can be performed. The most serious disadvantage is the time required to process bulk samples (and replicate samples) in the laboratory. In a recent survey of the land snails of southwestern Illinois (Coppolino 2009), a total of 240 one-liter leaf litter samples were collected from 60 sites, as one portion of the sampling method. These required an average of 30 minutes to sort and identify per sample, or a total of 120 hours for the entire study (not including the time required to identify and tabulate the specimens). Nevertheless, this amount of effort was necessary to achieve the goals of that investigation.

Cardboard sheets

Cardboard sheets or masonite boards have been advocated by some researchers for attracting land snails (Boag 1982, Hawkins *et al.* 1998). The sheets are placed at intervals within a site and left for predetermined periods of time, after which snails are recovered from the undersides of the sheets. Boag (1982) and Hawkins *et al.* (1998) each claimed that this method recovered species, especially slugs, which might not otherwise be collected. However, cardboard sheets have a number of limitations that can, in certain circumstances, outweigh the advantages. (1) A cardboard sheet is arguably not quantitative because attracted snails can migrate from outside the two-dimensional area, thus sampling more than its dimensions. (2) A sheet can be moved, by wind or the actions of animals, if not anchored in place. (3) A sheet is prone to warping and/or disintegration from excessive rainfall, reducing the effective surface area in contact with the substratum (although its effectiveness might in fact depend on a certain degree of moisture [Boag 1982, Hawkins *et al.* 1998], for better or for worse). (4) Some investigators have claimed that cardboard sheets have been ineffective at collecting any land snails (T. A. Pearce, pers. comm.). Nevertheless, they are valuable in qualitative surveys, especially if complementing other types of samples, for determining species richness or diversity.

Bulk sampling

It is well known that much of the terrestrial snail fauna constitutes microsnails, defined as individuals measuring 5 mm or less in greatest shell dimension as adults or juveniles. In many areas, tiny snails comprise most of the resident species (Pearce and Örstan 2006). As such, microsnails are often missed by visual searching. A frequently used method is bulk sampling leaf litter (and usually the top 2 cm of soil), where microsnails are most likely to be found (Pearce and Örstan 2006). This material is later sorted in the laboratory under magnification, sometimes assisted by passing through a graduated series of sieves to provide size fraction data (Emberton *et al.* 1996, Hotopp 2002, Pearce and Örstan 2006). This method can be conducted qualitatively or quantitatively, in the latter case by collecting and fully sorting a predetermined amount of leaf litter for each sample. The time required for processing bulk samples can be, as in the case of bulk material from quantitative quadrats, the greatest disadvantage.

LIVE VERSUS DEAD COLLECTING

In both qualitative and quantitative studies, the question arises whether to collect only empty shells, only live snails, or both. The choice again depends on the goals of the research, and each has its advocates. In studies with the goal of providing an accurate current estimate of snails living in a given area, only living specimens are counted (Boag 1982, Hawkins *et al.* 1998, Sulikowska-Drozd 2005). Preserved tissues or intact specimens from such studies can provide material for morphological and molecular investigations, potentially identifying species new to science, including cryptic species that often remain overlooked (Bickford *et al.* 2006). Two exceptions restrict the use of live-collecting, even if goals suggest otherwise: (1) the presence of rare or endangered species and (2) endemic species, even if in high abundance. The best examples of this are freshwater mussels, arguably among the most endangered invertebrates in North America (Cummings and Bogan 2006). In such cases, population densities should be estimated in some manner, but collecting severely limited to one or a few representatives (with proper permits, of course), or to empty shells only.

Other studies have included both live snails and empty shells to maximize diversity assessment. In the marine realm, Bieler and Mikkelsen (2004) judged dead shells to be essential to describing bivalve diversity in the Florida Keys, recovering 50.8% of a predicted species list through original samples including dead shells, compared to only 30.4% recovered by live-collected specimens alone. For land snails (Coppolino 2009), only 13% of the total snails recovered were live-collected, and most of the species considered rare in southern Illinois were collected from empty shells. In a land snail diversity study in Turkey, Örstan *et al.* (2005) found fourteen species (58% of total collected) as empty shells only and two species (8% of total) as live snails only. Results such as these indicate that total diversity is best estimated by collecting both live snails and empty shells. In some cases, species identification can be achieved from shell fragments. However, among the disadvantages of dead-collected shells is that the amount of time that the snail has been dead is largely unknown. The numbers of dead shells collected for a study can bias its results as abundances do not truly reflect those of living individuals (Pearce 2008). Pearce (2008) found several factors that influence the rate of shell decomposition, namely dissolution, breaking, and bioerosion; additionally, shells of different species were shown to decompose at different rates. Another uncertainty lies in translocation of empty shells, which, for instance, can roll downhill from a higher elevation, distorting accurate microhabitat records for those specimens. At some sites in Illinois (Coppolino 2009), great numbers of empty shells were found at the base of rock bluffs, as opposed to far fewer found at the tops.

ASSOCIATED DATA

Environmental data

In addition to basic locality information, the collection of associated data often includes ecological variables, both biotic and abiotic, in the land snail habitat. Shimek (1930) first recorded land snail associations with ecological variables. He described, for example, how snail assemblages changed over a geographic region in relation to the changing vegetation types. He suggested that forest types could serve as an index for snail populations, and *vice versa*. Since that time, numerous other examples have been published, commonly including soil factors, vegetation, topography, and/or climate data (Burch 1955, 1956, Wäreborn 1970, Coney *et al.* 1982, Emberton *et al.* 1996, Nekola 1999, Nekola and Smith 1999, Tattersfield *et al.* 2001). Some general correlations with ecological factors are recognized, such as high-calcium, high-pH soils supporting greater snail abundance and diversity (Burch 1955, Riggle 1976, Hotopp 2002), and such assumptions often steer project design. In practice, however, time and budgetary constraints are often the strongest determinants of which data to collect or exclude.

Habitat complexity in the broad sense has been suggested as influencing land snail abundance and diversity. A habitat complexity index was devised for use in a survey of southwestern Illinois land snails (Coppolino 2009), combining vegetation diversity, topographical changes, and exposed rock, which showed positive associations with species diversity and abundance in multiple regression analyses.

Soil variables such as moisture, calcium, and pH have been shown to positively influence land snail abundance and diversity (Burch 1955, Riggle 1976, Nekola 1999, Nekola and Smith 1999, Tattersfield *et al.* 2001, Hotopp 2002, Millar and Waite 2002, Coppolino 2009). Not surprisingly, calcium was strongly correlated with species diversity (although to a lesser degree with species abundances) in southwestern Illinois (Coppolino 2009). Soil factors that could negatively impact land snail populations, such as iron, were shown in a multiple regression as negatively correlated with species diversity (Coppolino 2009), and could also be worthy of measurement. Radioactive strontium, a product of nuclear fallout, behaves chemically like calcium and could therefore be used as a marker, suggesting further investigation of this topic (T. H. Nation, pers. comm.). Rock type can be closely related to soil calcium content, and has also been shown to be a significant factor in both land snail abundance and diversity (Nekola 1999, Nation 2005). As an alternative to collecting original soil and rock data for each station in a study, maps are often available for soil types from the U.S. Forestry Service (http://www.fs.fed.us/) and for underlying and exposed rock through the United States Geological Survey (http://www.usgs.gov/). The limitation of these data, however, is that

they seldom cover the study area exactly, thus requiring extrapolation or use of over-generalized data.

Vegetation type, at both broad and microhabitat levels, has been shown to influence snail abundance and diversity (Burch 1956, Karlin 1961, Grime and Blythe 1969, Beyer and Saari 1977, Nation 2007), and much remains to be learned about the relationships between land snails and particular plant species. In light of this concern, Karlin (1961) urged that vegetation records be reported in conjunction with land snail records. This could be an important element to a study despite the fact that soil type, climate, and other environmental factors in turn influence vegetation type, making exact associations between vegetation and snails difficult to discern. The complexity and interrelatedness of these and other biotic and abiotic variables, as well as their relative importance to land snail diversity and abundance, have been discussed by other authors (Wäreborn 1970, Coney *et al.* 1982, Nekola 2003, Nation 2007).

Ecological relationships

Most professional and public attention in wildlife conservation (and thus most of the available funding) lies above land snails in the food web, *i.e.*, land snail consumers. Nevertheless, recognition of imperiled "charismatic megafauna" that are also snail consumers could warrant a more serious approach to land snail conservation. One example of such a relationship was found by Graveland *et al.* (1994), in which a decline in forest passerines (song birds) was correlated with a decline in one of their main sources of dietary calcium—land snails—presumably due to acidic rainfall. Another good example is wild turkeys, which are popular game birds that easily draw the attention of conservation officials, wildlife managers, and the general public; it has been shown that female turkeys consume 40% more land snails during the egg-laying phase of the year (Beasom and Pattee 1978). Funding for land snail studies can also be facilitated by recognition of snail-predator relationships in which the predator is specialized or dependent on the snail for survival. One such example was a review of the state of knowledge about freshwater Florida Applesnails (*Pomacea paludosa* (Say, 1829)), which are the sole food item for the endangered Everglades or Snail Kite (*Rostrhamus sociabilis*), funded in 1989-1990 by Florida Game and Fresh Water Fish Commission (Turner and Mikkelsen 2004). Thus, recording data on birds and other malacophagous predators in a land snail study area could an important consideration for conservation.

Historical data

Because land snails have a "survive where you are" strategy, they cannot escape rapid alterations to their environment. Thus, when surveying an area of land for snails, it is worthwhile to investigate the history of the land, its use, and the major impact events upon it that potentially affect snail populations. Natural disturbances such as floods can alter the composition of snail populations in an otherwise amenable habitat (Coppolino 2009). The irreversible effects of human-induced interference can also greatly reduce or eliminate snail populations. For example, housing and commercial construction, agricultural use of land, roads and golf courses, and the chemicals used on them, potentially affect snail numbers (Kay 1995), and even recreational activities such as rock-climbing have been shown to adversely affect snail populations (McMillan 2003). Fire, whether from natural causes or human-induced, can negatively impact snail abundance and diversity (Nekola 2002, Kiss and Magnin 2003, Severns 2005). Artificial modifications to rivers cause permanent changes in a landscape, which can have detrimental consequences to the native snail species (Čejka *et al.* 2008). As studies such as these help us to understand changes in snail communities over history, it is prudent that we use this information to preserve areas that naturally support land snail populations. For example, in considering future land use plans, Örstan *et al.* (2005) emphasized that the land surrounding a unique snail habitat in Turkey was being threatened by the rapid human development.

Museum holdings and the literature can provide data to generate a baseline to compare with current investigations and are often the only reference baselines available. Hubricht's (1985) distribution guide remains the most comprehensive work of its kind, supplying locality data of land snails by county in each state in the eastern continental United States. However, caution must be exercised when interpreting presence/absence data in comparison with any kind of past collection records, because the absence of a species in a collection does not necessarily translate to absence in the area; it might merely have not been collected or recorded (Waggoner *et al.* 2006).

RECOMMENDATIONS FOR CONSERVATION PLANNING

Land snails are among the world's fastest declining faunas (Lydeard *et al.* 2004). As such, any land snail surveyor should feel obligated to identify species and populations that are most at risk in his or her survey area. Örstan *et al.* (2005) identified land snail populations in Turkey that were being reduced at the edges of a large, sprawling urban area. Furthermore, populations of some species, such as *Euchemotrema hubrichti* (Pilsbry, 1940) thrive in great abundance, but only over an extremely localized area (Anderson and Smith 2005). If the land supporting this endemic population is damaged, there could be little chance of recovery.

As in any biological study with complex variables and goals, multiple sampling methods are recommended in any survey that aims to improve land snail conservation. Combined

Table 1. Land snail collection methods, with advantages and disadvantages.

Method	Advantages	Disadvantages
Qualitative visual searching	- Simplest, least expensive - Recover rare or elusive species - Sample hard-to-sample habitats (*e.g.*, rock ledges)	- Restricted to large-bodied species visible in the field - Limited statistical applications
Quantitative quadrats and/or transects	- Most effective inter- and intra-site comparisons and statistical analyses - Can have time limit for the area to standardize search effort	- Location choice can be a potential bias
Bulk (leaf litter) samples	- Recover microsnails - Qualitative or quantitative applications	- High time investment required to sort samples
Cardboard sheets	- Attract elusive species, especially slugs	- Quantitative nature questionable - Moveable over time - Prone to warping and/or disintegration - Ineffective in some studies

quantitative/qualitative survey methods are most effective in maximizing diversity assessment, usually important in such cases. The technique itself need not be elaborate; for example, the combination of visual searching, quantitative quadrats, and bulk leaf litter/soil samples for microsnails might provide excellent coverage. The added inclusion of ecological data increases the breadth and potential usefulness of the study. Partnerships between malacologists and botanists, ornithologists, geologists, soil scientists, and others are almost always fruitful; some examples include works by Grime and Blythe (1969), Beyer and Saari (1977), Beasom and Pattee (1978), Coney *et al.* (1982), Graveland *et al.* (1994), Tattersfield *et al.* (2001), Kiss and Magnin (2003), McMillan *et al.* (2003), and Čejka *et al.* (2008). Such collaborative studies are disseminated to a larger body of scientists, and importantly, more readily reach the interest of land and wildlife conservation officials.

Although the definitions of "rare" species vary with context, a rare land snail is generally considered to occupy a limited geographical range or niche, regardless of local abundance (Bengtsson *et al.* 1994). Land snail "hotspots," or localities that support rare or endemic species, have been identified to assist conservation efforts; Sólymos and Fehér (2005) indicated areas of priority by analyzing relationships between the protection status and rarity of each land snail species in the study area. However, it should be remembered that "rarity" can change over time, *e.g.*, actually increasing with changing environmental conditions or effectively decreasing with sampling that reveals additional populations. Cameron and Pokryszko (2005) noted that most areas are visited only once for formal land snail surveys. Although such one-time surveys provide valuable baseline inventory data, the effects of season, weather, and other natural events can bias results. Multiple surveys of one area over time can correct for this bias. Ideally, a survey should be performed at regular intervals, so that not only a baseline inventory can be achieved, but also so that natural fluctuations in population composition can be understood.

As a final note, regular communication with natural resource and wildlife officials is essential to alert them of land snail species in need of conservation. The fact that snails represent a vital part of the terrestrial ecosystem can be taught through educational programs and publications. A malacologist's presence among state and federal wildlife agencies can foster only a better understanding of the importance of land snails. Efforts to continually assess the conservation status of land snails should be implemented whenever possible.

CONCLUSIONS

In summary, land snail surveys can be effectively accomplished using a variety of methods (Table 1), each with its own advantages and disadvantages. The choice of which method(s) to use depends on a myriad of questions, related to physical factors of the survey area, the questions that the survey is designed to address, and the practical limitations (*e.g.*, budget and time constraints) of the project. Given the vulnerability of land snail populations across the globe, surveyors should keep conservation issues in mind during the design phase, to include appropriate environmental and ecological parameters that will increase the usefulness of the results for future applications.

ACKNOWLEDGMENTS

I wish to thank Kathryn Perez for the gracious invitation to participate in the Land Snail Symposium at the American Malacological Society meeting in 2008. I also

extend my gratitude toward Paula M. Mikkelsen and Travis H. (Rocky) Nation for helpful comments and suggestions that greatly improved this paper. Finally, I would like to express appreciation for my opportunity to work under U.S. Fish and Wildlife Service/Illinois Department of Natural Resources State Wildlife Grant T-32-P, *A quantitative study of land snail diversity across multiple habitat types in southern Illinois*, received by Frank (Andy) Anderson, Department of Zoology, Southern Illinois University, Carbondale.

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Submitted: 9 February 2009; **accepted**: 2 July 2009;
final revisions received: 14 October 2009